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(54) **DUTY CYCLE CONTROL METHOD, POWER SUPPLY SYSTEM AND POWER CONVERTER USING THE SAME**

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(60) Provisional application No. 61/229,376, filed on Jul. 29, 2009.

(30) **Foreign Application Priority Data**

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H02M 3/335 (2006.01)
H02M 1/00 (2007.01)

(52) **U.S. Cl.**
CPC ***H02M 3/33507*** (2013.01); ***H02M 3/33576*** (2013.01); ***H02M 3/33592*** (2013.01); *H02M 2001/0022* (2013.01)

(58) **Field of Classification Search**
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USPC 323/234, 237, 265, 282–285
See application file for complete search history.

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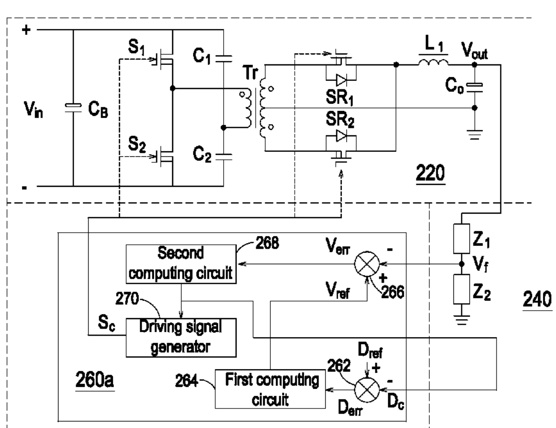
(57) **ABSTRACT**

A power converter includes a power module, a feedback module, and a control module. The power module is used for converting an input voltage into an output voltage. The feedback module is electrically connected with the power module for generating a feedback voltage according to the output voltage. The control module is electrically connected with the feedback module and the power module for comparing a reference duty cycle value with a duty cycle, generating a variable reference voltage according to the comparison between the reference duty cycle value and the duty cycle, comparing the variable reference voltage with the feedback voltage, and adjusting the duty cycle according to the comparison between the variable reference voltage and the feedback voltage.

11 Claims, 6 Drawing Sheets



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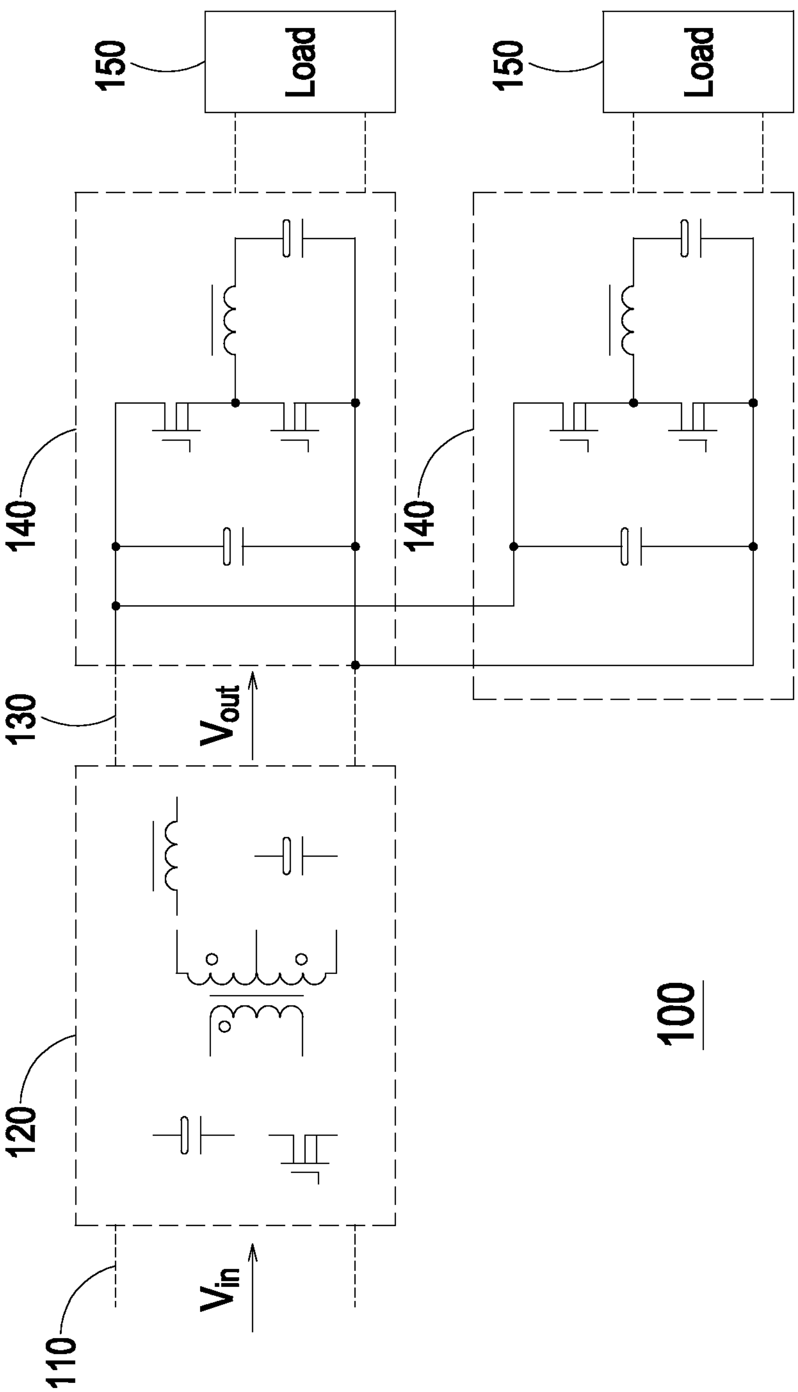


FIG. 1

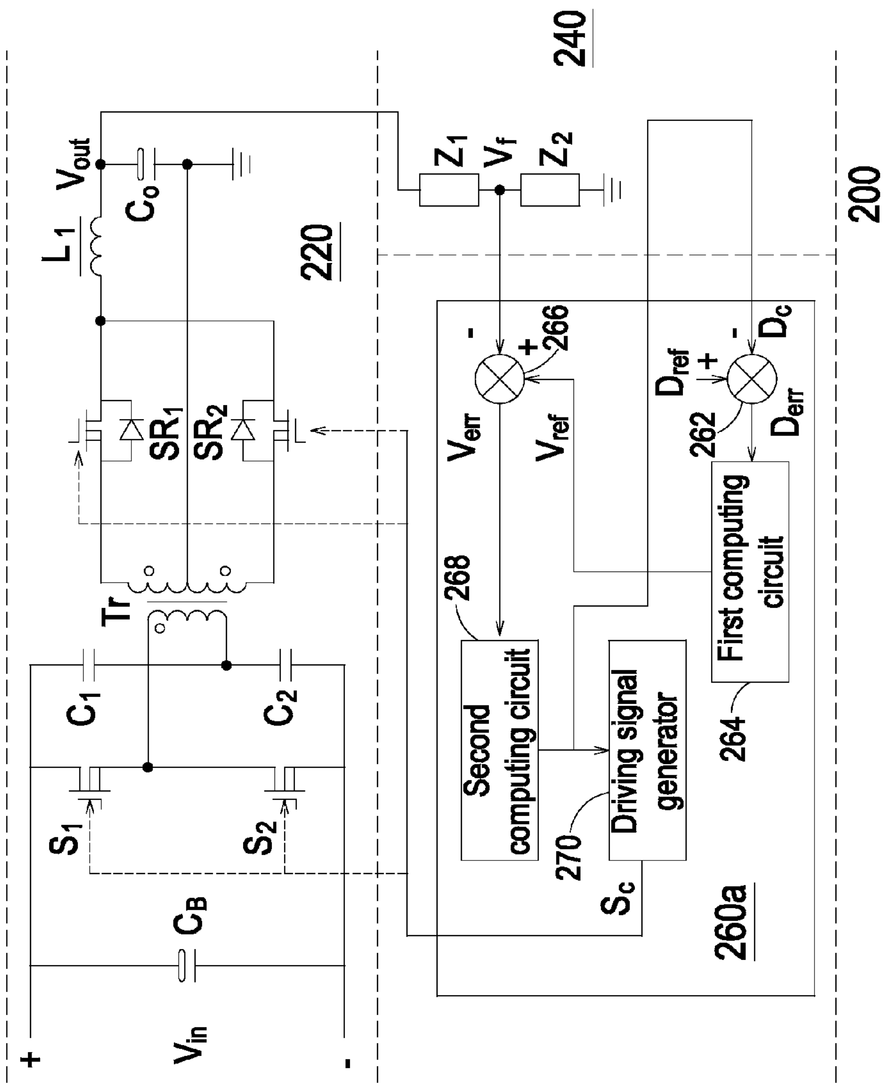

Vout
L1
Co
SR1
SR2
Tr
C1
C2
S1
S2
CB
Vin
220
240
200
Z1
Vf
Z2
266
Verr
Vref
Dref
Dc
262
Derr
First computing circuit
264
268
Second computing circuit
Driving signal generator
270
Sc
260a

FIG. 2

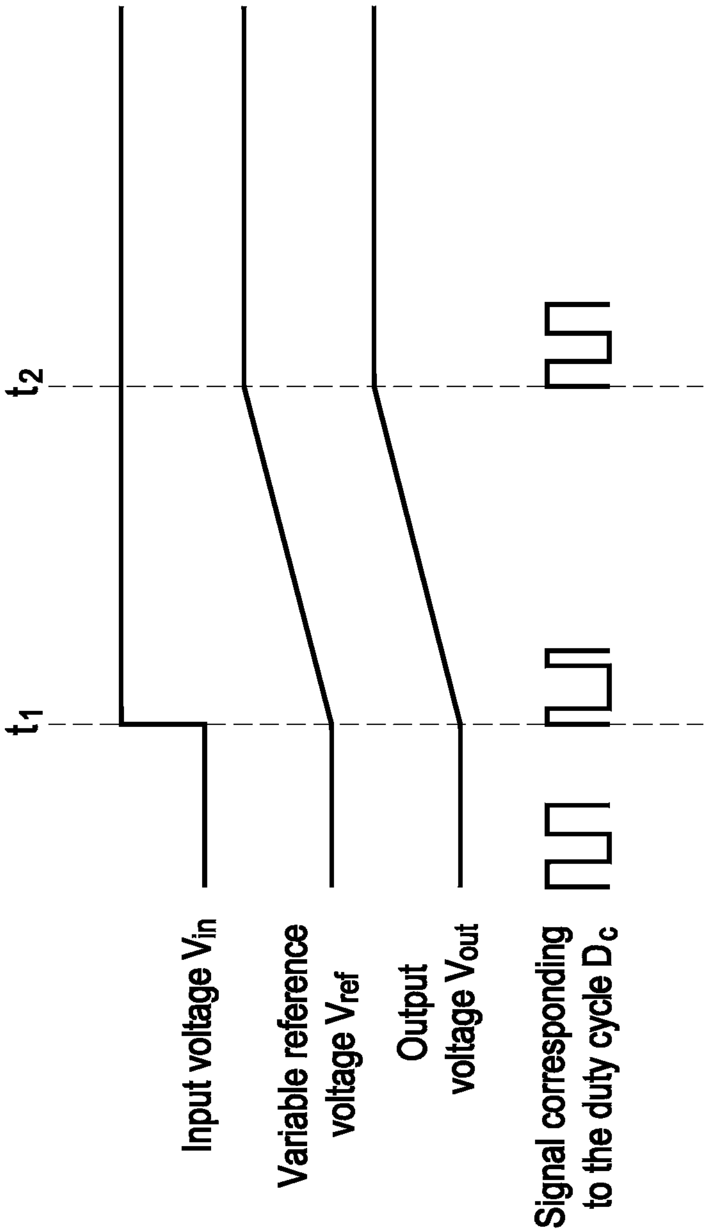
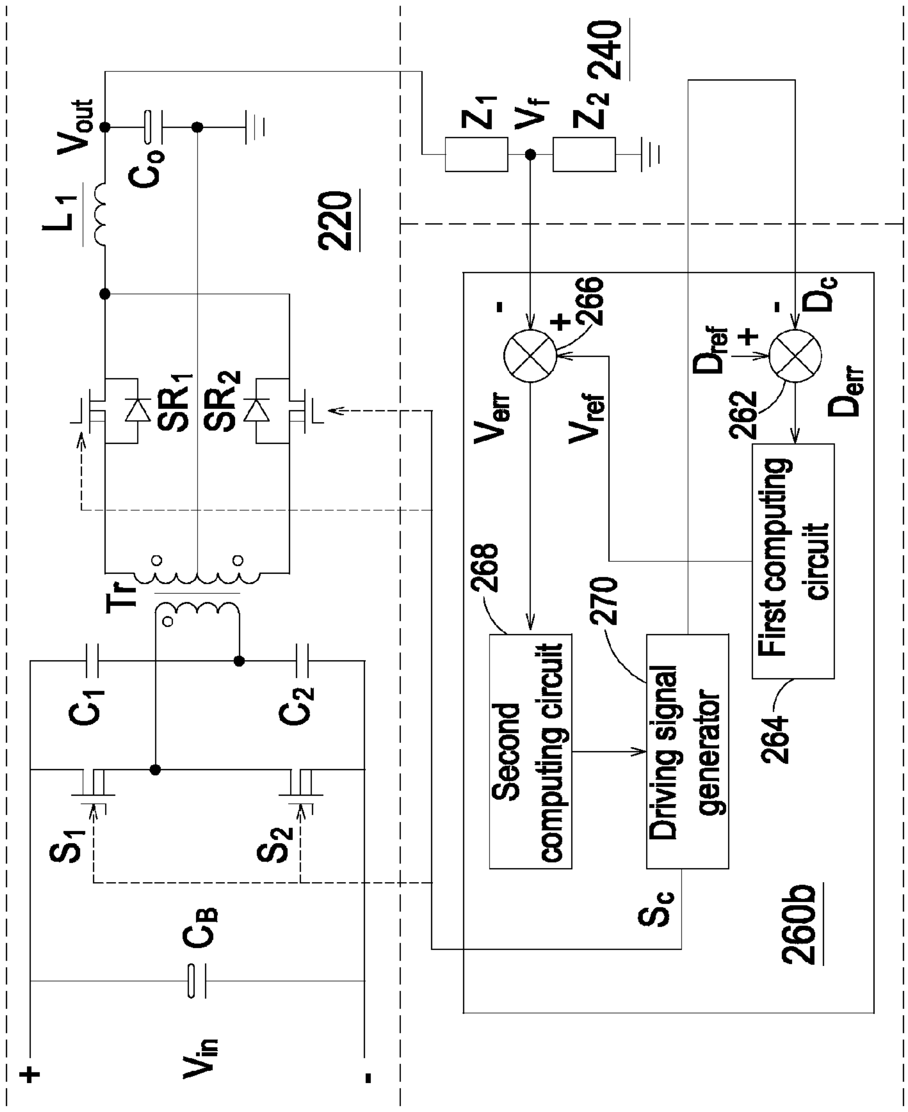
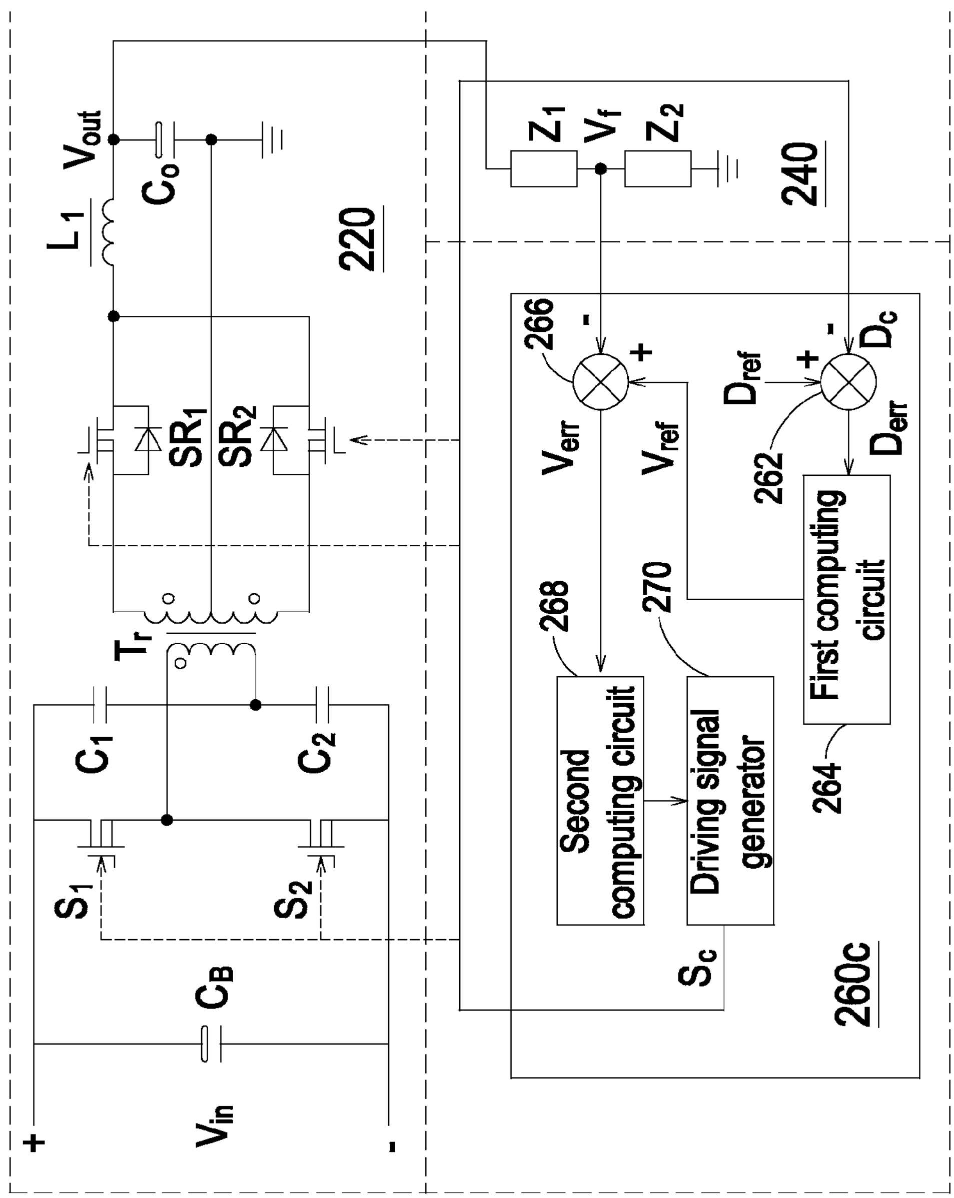

t_1
t_2
Input voltage V_{in}
Variable reference voltage V_{ref}
Output voltage V_{out}
Signal corresponding to the duty cycle D_c

FIG. 3



V_{in}
C_B
S_1
S_2
C_1
C_2
Tr
SR_1
SR_2
L_1
V_{out}
C_o
220
Z_1
V_f
Z_2
240
200
266
V_{err}
V_{ref}
D_{ref}
D_c
262
D_{err}
268
Second computing circuit
270
Driving signal generator
First computing circuit
264
S_c
260b

FIG. 4



Vin
CB
S1
S2
C1
C2
Tr
SR1
SR2
L1
Vout
Co
220
Z1
Vf
Z2
240
200
266
Verr
Vref
Dref
Dc
Derr
262
268
270
264
Second computing circuit
Driving signal generator
First computing circuit
Sc
260c

FIG. 5

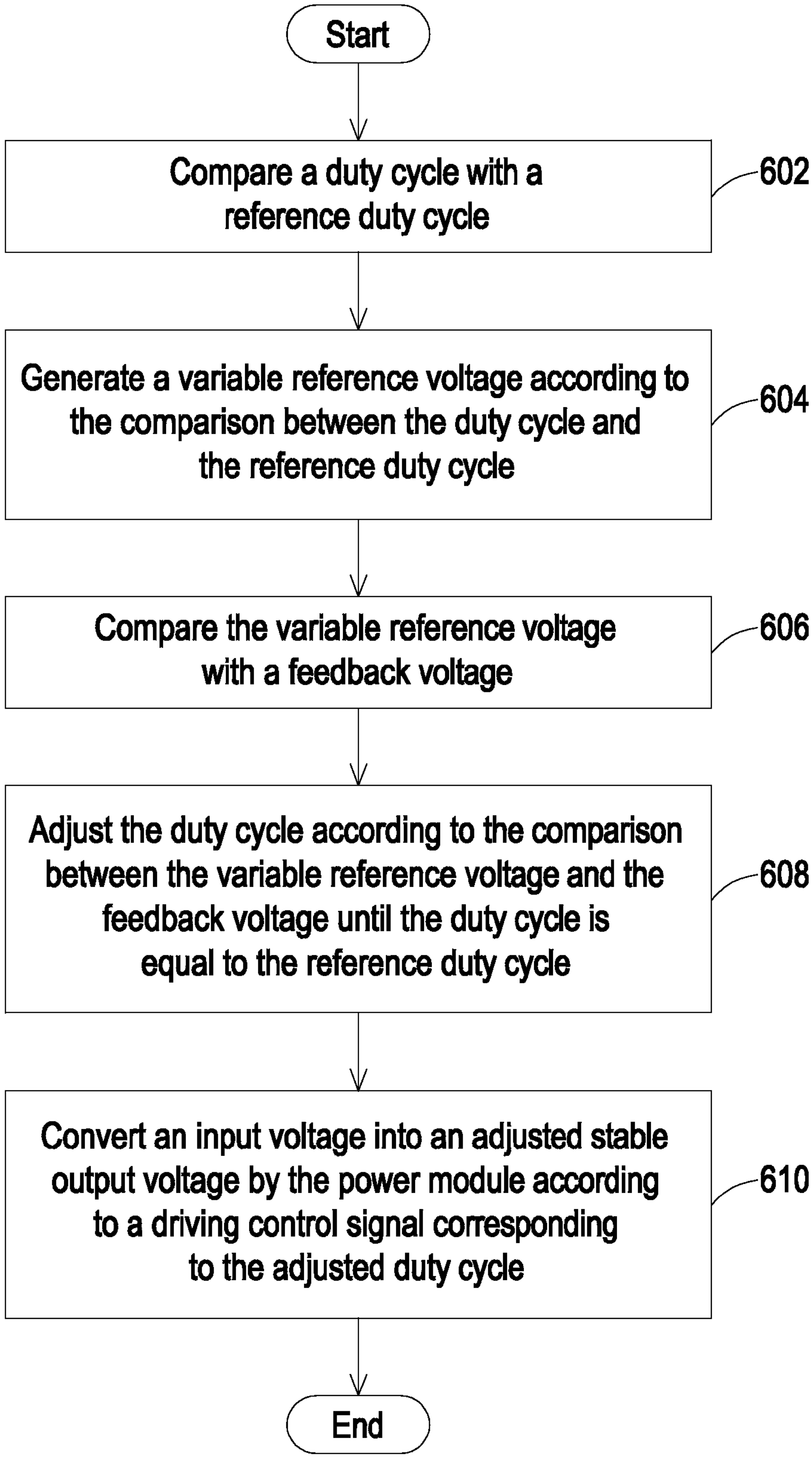

Start
Compare a duty cycle with a reference duty cycle
602
Generate a variable reference voltage according to the comparison between the duty cycle and the reference duty cycle
604
Compare the variable reference voltage with a feedback voltage
606
Adjust the duty cycle according to the comparison between the variable reference voltage and the feedback voltage until the duty cycle is equal to the reference duty cycle
608
Convert an input voltage into an adjusted stable output voltage by the power module according to a driving control signal corresponding to the adjusted duty cycle
610
End

FIG. 6

DUTY CYCLE CONTROL METHOD, POWER SUPPLY SYSTEM AND POWER CONVERTER USING THE SAME

CROSS-REFERENCE TO RELATED APPLICATIONS

The present application is a continuation-in-part of U.S. patent application Ser. No. 12/845,898 entitled "VOLTAGE-REGULATING CIRCUIT WITH INPUT VOLTAGE DETECTING CIRCUIT AND PARALLEL VOLTAGE-REGULATING CIRCUIT SYSTEM USING THE SAME" filed on Jul. 29, 2010, which claims the benefit of U.S. Provisional Application No. 61/229,376, filed on Jul. 29, 2009, and entitled "A HIGH EFFICIENCY POWER CONVERTER", the entirety of which is hereby incorporated by reference. This application also claims priority benefits of CN application serial No. 201210357145.8, filed on Sep. 21, 2012, the disclosures of which are incorporated herein by reference.

FIELD OF THE INVENTION

The present invention relates to a power supply system, and more particularly to a power converter of a power supply system.

BACKGROUND OF THE INVENTION

In a conventional embedded power supply, a printed circuit board (PCB) with multiple thick copper layers and a special process of surface-mounting power devices are usually employed to reduce the overall volume and increase the reliability. Consequently, the embedded power supply is widely used in wireless networks, fiber-optic network apparatuses, servers and data storage devices.

Generally, when a full-regulated converter is applied to the conventional embedded power supply, the efficiency of the full-regulated converter is restricted and fails to be effectively enhanced. For example, in the full-regulated converter, the output voltage from the power module is fed back and compared with a fixed reference voltage. According to the comparing result, a control module adjusts a driving signal. According to the driving signal, the output voltage of the power module is correspondingly adjusted. Consequently, the magnitude of the output voltage is determined according to the comparison between the fixed reference voltage and the feedback voltage. Moreover, for allowing the power module to generate a corresponding output voltage according to the input voltage, the turn ratio of the transformer of the power module should be very small. Consequently, at the minimum input voltage, the power module can still generate the output voltage corresponding to the fixed reference voltage. Under this circumstance, the power module can be operated in the full-regulated status. However, if the turn ratio of the transformer of the power module is too large, the power module fails to generate the output voltage corresponding to the fixed reference voltage. Under this circumstance, the feedback adjusting function of the power module according to the output voltage will be lost.

Due to the limitation of the turn ratio of the transformer, when the power module is operated at a high input voltage, the output inductor is usually subjected to a very high volt-second value (V×t). Consequently, the output inductor should have a large-sized magnetic core or more winding turns. Under this circumstance, the power density of the power module is limited and the power module fails to be enhanced.

SUMMARY OF THE INVENTION

The present invention provides a power supply system, a power converter, and a voltage regulating method. As the input voltage is increased, the output voltage converted from the input voltage is gradually adjusted. Consequently, the output inductor is subjected to a reduced volt-second value.

In accordance with an aspect of the present invention, there is provided a power converter. The power converter includes a power module, a feedback module, and a control module. The power module is used for converting an input voltage into an output voltage. The feedback module is electrically connected with the power module for generating a feedback voltage according to the output voltage. The control module is electrically connected with the feedback module and the power module for comparing a reference duty cycle value with a duty cycle, generating a variable reference voltage according to the comparison between the reference duty cycle value and the duty cycle, comparing the variable reference voltage with the feedback voltage, and adjusting the duty cycle according to the comparison between the variable reference voltage and the feedback voltage.

In an embodiment, when the input voltage is changed, the variable reference voltage is adjusted by the control module, the duty cycle is correspondingly adjusted by the control module, and a driving control signal corresponding to the adjusted duty cycle is generated by the control module so as to control the power module.

In an embodiment, the control module further comprises a first comparing circuit and a first computing circuit. The first comparing circuit is used for comparing the reference duty cycle value with the duty cycle, thereby generating an error duty cycle. The first computing circuit is electrically connected with the first comparing circuit for computing the error duty cycle, thereby generating and adjusting the variable reference voltage.

In an embodiment, the control module further comprises a second comparing circuit, a second computing circuit, and a driving signal generator. The second comparing circuit is electrically connected with the first computing circuit and the feedback module for comparing the variable reference voltage with the feedback voltage, thereby generating an error voltage. The second computing circuit is electrically connected with the second comparing circuit for computing the error voltage, thereby generating and adjusting the duty cycle. The driving signal generator is electrically connected with the second computing circuit and the power module for receiving the duty cycle from the second computing circuit and generating the driving control signal corresponding to the duty cycle.

In an embodiment, the first comparing circuit is electrically connected with the second computing circuit for receiving the duty cycle from the second computing circuit.

In an embodiment, the first comparing circuit is electrically connected with the driving signal generator for retrieving the duty cycle from the driving signal generator.

In an embodiment, after the driving control signal for controlling the power module is outputted from the control module, the driving control signal is fed back to the control module. The fed-back driving control signal is received by the first comparing circuit, so that the corresponding duty cycle is retrieved from the driving control signal.

In an embodiment, when the input voltage is increased, the variable reference voltage is gradually increased, and the duty cycle is gradually increased by the control module.

In accordance with another aspect of the present invention, there is provided a power supply system. The power supply system includes a high voltage bus, a low voltage bus, a power converter, and a plurality of supply voltage generation circuits. The power converter is electrically connected between the high voltage bus and the low voltage bus and comprises a control module for comparing a reference duty cycle value with a duty cycle, generating a variable reference voltage according to the comparison between the reference duty cycle value and the duty cycle, adjusting the duty cycle according to the comparison between the variable reference voltage and a feedback voltage, and generating a driving control signal corresponding to the adjusted duty cycle, thereby adjusting an output voltage from the power converter. The supply voltage generation circuits are electrically connected with each other in parallel and electrically connected to the low voltage bus for converting the output voltage into respective supply voltages, thereby providing to corresponding loads.

In an embodiment, the control module of the power converter further comprises a first comparing circuit and a first computing circuit. The first comparing circuit is used for comparing the reference duty cycle value with the duty cycle, thereby generating an error duty cycle. The first computing circuit is electrically connected with the first comparing circuit for computing the error duty cycle, thereby generating and adjusting the variable reference voltage.

In an embodiment, the control module of the power converter further comprises a second comparing circuit, a second computing circuit, and a driving signal generator. The second comparing circuit is electrically connected with the first computing circuit and the feedback module for comparing the variable reference voltage with the feedback voltage, thereby generating an error voltage. The second computing circuit is electrically connected with the second comparing circuit for computing the error voltage, thereby generating and adjusting the duty cycle. The driving signal generator is electrically connected with the second computing circuit for receiving the duty cycle from the second computing circuit and generating the driving control signal corresponding to the duty cycle.

In an embodiment, the first comparing circuit is electrically connected with the second computing circuit for receiving the duty cycle from the second computing circuit.

In an embodiment, the first comparing circuit is electrically connected with the driving signal generator for retrieving the duty cycle from the driving signal generator.

In an embodiment, after the driving control signal is outputted from the control module, the driving control signal is fed back to the control module, wherein the fed-back driving control signal is received by the first comparing circuit, so that the corresponding duty cycle is retrieved from the driving control signal.

In an embodiment, when an input voltage of the power converter is changed, the variable reference voltage is adjusted by the control module. When the input voltage is increased, the variable reference voltage is increased, the duty cycle is gradually increased by the control module, and the output voltage is gradually increased according to the driving control signal.

In accordance with a further aspect of the present invention, there is provided a voltage regulating method. Firstly, a duty cycle is compared with a reference duty cycle value. Then, a variable reference voltage is generated according to the comparison between the duty cycle and the reference duty cycle value. Then, the variable reference voltage is compared with a feedback voltage. Then, the duty cycle is adjusted according to the comparison between the variable reference voltage and the feedback voltage. An input voltage is converted into an adjusted output voltage by a power module according to a driving control signal corresponding to the adjusted duty cycle.

In an embodiment, the duty cycle is generated and adjusted by a computing circuit.

In an embodiment, the driving control signal is generated by a driving signal generator, and the duty cycle to be compared with the reference duty cycle value is retrieved from the driving signal generator.

In an embodiment, the duty cycle to be compared with the reference duty cycle value is retrieved from the driving control signal.

In an embodiment, when the input voltage is changed, the variable reference voltage is correspondingly adjusted. When the input voltage is increased, the variable reference voltage is gradually increased, and the duty cycle is adjusted to be gradually increased.

The above contents of the present invention will become more readily apparent to those ordinarily skilled in the art after reviewing the following detailed description and accompanying drawings, in which:

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic circuit diagram illustrating a power supply system according to an embodiment of the present invention;

FIG. **2** is a schematic circuit diagram illustrating a first exemplary power converter used in the power supply system of FIG. **1**;

FIG. **3** is a schematic timing waveform diagram illustrating the input voltage, the variable reference voltage, the output voltage and the signal corresponding to the duty cycle processed in the power converter of FIG. **2**;

FIG. **4** is a schematic circuit diagram illustrating a second exemplary power converter used in the power supply system of FIG. **1**;

FIG. **5** is a schematic circuit diagram illustrating a third exemplary power converter used in the power supply system of FIG. **1**; and

FIG. **6** is a flowchart illustrating a voltage regulating method according to an embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

The present invention will now be described more specifically with reference to the following embodiments. It is to be noted that the following descriptions of preferred embodiments of this invention are presented herein for purpose of illustration and description only. It is not intended to be exhaustive or to be limited to the precise form disclosed.

Unless limited otherwise, the terms “connected” or “coupled” are used broadly and encompass direct and indirect connections or couplings of two or more components.

FIG. **1** is a schematic circuit diagram illustrating a power supply system according to an embodiment of the present invention. As shown in FIG. **1**, the power supply system **100** comprises a high voltage bus **110**, a power converter **120**, a low voltage bus **130**, and a plurality of supply voltage generation circuits **140**. The power converter **120** is electrically connected between the high voltage bus **110** and the low voltage bus **130**. An input voltage V_{in} is received by the power converter **120** through the high voltage bus **110**. Moreover, the input voltage V_{in} is converted into an output voltage V_{out} by the power converter **120**, and the output voltage V_{out} is transmitted through the low voltage bus **130**. The supply voltage generation circuits **140** are electrically connected with each other in parallel and electrically connected to the low voltage bus **130**. The supply voltage generation circuits **140** are used for converting the output voltage V_{out} into respective supply voltages, thereby providing to corresponding loads **150**.

FIG. **2** is a schematic circuit diagram illustrating a first exemplary power converter used in the power supply system of FIG. **1**. The power converter **200** of FIG. **2** may be applied to the power supply system **100** of FIG. **1**, but is not limited thereto. As shown in FIG. **2**, the power converter **200** comprises a power module **220**, a feedback module **240**, and a control module **260***a*. The power module **220** is used for converting the input voltage V_{in} into the output voltage V_{out}. The feedback module **240** is electrically connected with the power module **220** for generating a feedback voltage V_f corresponding to the output voltage V_{out}. The control module **260***a* is electrically connected with the feedback module **240** and the power module **220** for comparing a reference duty cycle value D_{ref} and a duty cycle D_c. According to the comparison between the reference duty cycle value D_{ref} and the duty cycle D_c, the control module **260***a* generates a corresponding variable reference voltage V_{ref}. Moreover, according to the comparison between the variable reference voltage V_{ref} and the feedback voltage V_f, the control module **260***a* correspondingly adjusts the duty cycle value D_c. According to the practical requirements, the reference duty cycle value D_{ref} may be set as a constant value or a constant ratio (e.g. 50%).

In this context, it is to be noted that the reference duty cycle value D_{ref} and the duty cycle D_c may indicate values or signals corresponding to the values. In other words, the control module **260***a* may receive two signals corresponding to the reference duty cycle value D_{ref} and the duty cycle D_c and compare these two signals.

In an embodiment, as the input voltage V_{in} is changed, the control module **260***a* will adjust the variable reference voltage V_{ref}, thereby correspondingly adjusting the duty cycle D_c. Moreover, according to the adjusted duty cycle D_c, the control module **260***a* generates a corresponding driving control signal S_c. Since the conversion of the input voltage V_{in} by the power module **220** is correspondingly controlled, the output voltage V_{out} from the power converter **200** will be correspondingly adjusted.

In practice, the control module **260***a* or the following control module (e.g. the control module **260***b* of FIG. **4** or the control module **260***c* of FIG. **5**) may be implemented by a digital controller (or a control chip) or an analog controller (or a control chip).

Please refer to FIG. **2** again. The power module **220** comprises a first switch element S_1, a second switch element S_2, a first capacitive voltage divider C_1, a second capacitive voltage divider C_2, a transformer Tr, a first rectifier switch SR_1, a second rectifier switch SR_2, a filtering inductor L_1, and a filtering capacitor C_o. The first switch element S_1 and the second switch element S_2 are electrically connected with the first capacitive voltage divider C_1 and the second capacitive voltage divider C_2 in parallel. Moreover, according to a driving control signal S_c from the control module **260***a*, the first switch element S_1 and the second switch element S_2 are controlled to be conducted (or turned on) or shut off (or turned off). The first capacitive voltage divider C_1 and the second capacitive voltage divider C_2 are connected with each other in series. By the first capacitive voltage divider C_1 and the second capacitive voltage divider C_2, the input voltage V_{in} is subjected to voltage division. Consequently, a divided voltage is provided to a primary winding of the transformer Tr. The first rectifier switch SR_1 and the second rectifier switch SR_2 are connected with a secondary winding of the transformer Tr for performing synchronous rectification. The filtering inductor L_1 and the filtering capacitor C_o are serially connected with the first rectifier switch SR_1 for filtering. In an embodiment, the power module **220** further comprises a filtering capacitor C_B electrically connected with the first switch element S_1 and the second switch element S_2 in parallel for filtering.

The feedback module **240** comprises a first impedance Z_1 and a second impedance Z_2. By the first impedance Z_1 and the second impedance Z_2, the output voltage V_{out} is subjected to voltage division. Consequently, a feedback voltage V_f corresponding to the output voltage V_{out} is generated.

Alternatively, in some other embodiments, the output current corresponding to the output voltage V_{out} may be subjected to current division by the feedback module **240**. Consequently, a feedback current signal corresponding to the output current is generated. By comparing the feedback current signal with a variable reference current signal, the control module **260**a adjusts duty cycle according to the comparing result. The variable reference current signal may be determined according to the comparison between the reference duty cycle value and the duty cycle. In other words, the feedback signal generated by the feedback module **240** may be a feedback voltage signal or a feedback current signal. Moreover, the function and operation of the control module **260**a may be correspondingly adjusted according to the feedback voltage signal or the feedback current signal.

The control module **260**a comprises a first comparing circuit **262**, a first computing circuit **264**, a second comparing circuit **266**, a second computing circuit **268**, and a driving signal generator **270**. The first comparing circuit **262** is used for comparing the reference duty cycle value D_{ref} with the duty cycle D_c, thereby generating an error duty cycle D_{err}. The first computing circuit **264** is electrically connected with the first comparing circuit **262** for computing the error duty cycle D_{err}, thereby generating and adjusting the variable reference voltage V_{ref}. The second comparing circuit **266** is electrically connected with the first computing circuit **264** and the feedback module **240** for comparing the variable reference voltage V_{ref} with the feedback voltage V_f from the feedback module **240**, thereby generating an error voltage V_{err}. The second computing circuit **268** is electrically connected with the second comparing circuit **266** for computing the error voltage V_{err}, thereby generating and adjusting the duty cycle D_c. The driving signal generator **270** is electrically connected with the second computing circuit **268** and the power module **220** for receiving the duty cycle D_c from the second computing circuit **268** and generating the driving control signal S_c corresponding to the duty cycle D_c.

In this embodiment, the first comparing circuit **262** is electrically connected with the second computing circuit **268** for receiving the duty cycle D_c from the second computing circuit **268**. The duty cycle D_c is generated and adjusted by the second computing circuit **268**. Moreover, the adjusted duty cycle D_c is further fed back to the first comparing circuit **262** in order to be compared with the reference duty cycle value D_{ref}.

FIG. **3** is a schematic timing waveform diagram illustrating the input voltage, the variable reference voltage, the output voltage and the signal corresponding to the duty cycle processed in the power converter of FIG. **2**. Please refer to FIGS. **2** and **3**. At the time point t_1, the input voltage V_{in} is increased or changed to a high-level state. Since the variable reference voltage V_{ref} fails to be immediately changed in the short time, the control module **260***a* will reduce the duty cycle D_c. For example, the duty cycle D_c is adjusted to be smaller than the reference duty cycle value D_{ref}. Under this circumstance, the output voltage V_{out} is not changed immediately. As the duty cycle D_c is gradually increased, the output voltage V_{out} and the corresponding feedback voltage V_f are changed with the variable reference voltage V_{ref}.

From the time point t_1 to the time point t_2, the duty cycle D_c is smaller than the reference duty cycle value D_{ref}. After the fed-back duty cycle D_c is compared and computed, the variable reference voltage V_{ref} is gradually increased by the first computing circuit **264** according to the comparing result and the computing result. As the variable reference voltage V_{ref} is gradually increased, the variable reference voltage V_{ref} is equal to the feedback voltage V_f at the time point t_2. Moreover, after the gradually-increased variable reference voltage V_{ref} is compared and computed, the duty cycle D_c is gradually increased by the second computing circuit **268** according to the comparing result and the computing result. As the duty cycle D_c is gradually increased, the duty cycle D_c is equal to the reference duty cycle value D_{ref} at the time point t_2.

Moreover, according to the duty cycle D_c that is changed from the time point t_1 to the time point t_2, the driving signal generator **270** generates the driving control signal S_c. According to the driving control signal S_c, the power module **220** adjusted the output voltage V_{out}. At the time point t_2, the adjusted output voltage V_{out} is increased to a constant value. Consequently, the power converter **200** is in a steady state.

From the above discussions, the variable reference voltage V_{ref} is changed by adjusting the duty cycle D_c. As the input voltage V_{in} is changed, the output voltage V_{out} from the power converter **200** is not changed immediately, but the output voltage V_{out} is changed with the variable reference voltage V_{ref}. That is, if the input voltage V_{in} is changed, the output voltage V_{out} can be gradually adjusted by the power converter **200**. Under this circumstance, the output inductor is subjected to a reduced volt-second value (V×t). Since the output inductor does not need to have a large-sized magnetic core or more winding turns, the power density of the power module **220** is increased, and the efficiency of the power converter is enhanced.

FIG. **4** is a schematic circuit diagram illustrating a second exemplary power converter used in the power supply system of FIG. **1**. As shown in FIG. **4**, the power converter **200** comprises a power module **220**, a feedback module **240**, and a control module **260***b*. In comparison with FIG. **2**, the control module **260***b* is distinguished. In the control module **260***b* of this embodiment, the first comparing circuit **262** is electrically connected with the driving signal generator **270** for retrieving the duty cycle D_c from the driving signal generator **270**. Moreover, the duty cycle D_c retrieved from the driving signal generator **270** is compared with the reference duty cycle value D_{ref} by the first comparing circuit **262**.

The operations of the control module **260***b* and the relationship between the control module **260***b*, the power module **220** and the feedback module **240** are similar to those of FIG. **2**, and are not redundantly described herein. The operations of the components of the control module **260***b* and the relationships between these components are similar to those of FIG. **2**, and are not redundantly described herein.

FIG. **5** is a schematic circuit diagram illustrating a third exemplary power converter used in the power supply system of FIG. **1**. As shown in FIG. **5**, the power converter **200** comprises a power module **220**, a feedback module **240**, and a control module **260***c*. In comparison with FIG. **2**, the control module **260***c* is distinguished. In this embodiment, after the driving control signal S_c is outputted from the control module **260***c*, the driving control signal S_c is fed back to the control module **260***c*. The fed-back driving control signal S_c is received by the first comparing circuit **262**, so that the corresponding duty cycle is retrieved from the driving control signal. Moreover, the duty cycle D_c retrieved from the driving signal generator **270** is compared with the reference duty cycle value D_{ref} by the first comparing circuit **262**.

The operations of the control module **260***c* and the relationship between the control module **260***c*, the power module **220** and the feedback module **240** are similar to those of FIG. **2**, and are not redundantly described herein. The operations of the components of the control module **260***c* and the relationships between these components are similar to those of FIG. **2**, and are not redundantly described herein.

FIG. **6** is a flowchart illustrating a voltage regulating method according to an embodiment of the present invention. Hereinafter, the voltage regulating method will be illustrated with reference to the circuit diagram of FIG. **2** and the flowchart of FIG. **6**. Firstly, a duty cycle D_c is compared with a reference duty cycle value D_{ref} (Step **602**). Then, a variable reference voltage V_{ref} is generated according to the comparison between the duty cycle D_c and the reference duty cycle value D_{ref} (Step **604**). Then, the variable reference voltage V_{ref} is compared with a feedback voltage V_f (Step **606**). Then, according to the comparison between the variable reference voltage V_{ref} and the feedback voltage V_f, the duty cycle D_c is adjusted until the duty cycle D_c is equal to the reference duty cycle value D_{ref} (Step **608**). Then, according to a driving control signal S_c corresponding to the adjusted duty cycle D_c, an input voltage V_{in} is converted into an adjusted stable output voltage by the power module **220**.

In an embodiment of the voltage regulating method, the duty cycle D_c is generated and adjusted by the second computing circuit **268**.

In an embodiment of the voltage regulating method, as the input voltage V_{in} is changed, the variable reference voltage V_{ref} is correspondingly adjusted. In particular, as the input voltage V_{in} is increased, the variable reference voltage V_{ref} is gradually increased, and the duty cycle D_c is adjusted to be gradually increased.

In an embodiment of the voltage regulating method, the duty cycle D_c is retrieved from the driving signal generator **270**. As the input voltage V_{in} is increased, the variable reference voltage V_{ref} is gradually increased, and the duty cycle D_c is adjusted to be gradually increased.

In an embodiment of the voltage regulating method, the duty cycle D_c is retrieved from the driving control signal S_c. After the driving control signal S_c is outputted from the control module **260***c*, the driving control signal S_c is fed back to the control module **260***c* and received by the first comparing circuit **262** (see FIG. **5**). As the input voltage V_{in} is increased, the variable reference voltage V_{ref} is gradually increased, and the duty cycle D_c is adjusted to be gradually increased.

Unless specifically stated, the steps of the voltage regulating method of the above embodiment may be varied according to the practical requirements. The flowchart of the voltage regulating method of FIG. **6** is presented herein for purpose of illustration and description only.

From the above descriptions, the present invention provides a power supply system, a power converter, and a voltage regulating method. As the input voltage is changed, the output voltage is gradually adjusted. Consequently, the output inductor is subjected to a reduced volt-second value (V×t). Since the output inductor does not need to have a large-sized magnetic core or more winding turns, the power density of the power module is increased, and the efficiency of the power converter is enhanced.

While the invention has been described in terms of what is presently considered to be the most practical and preferred embodiments, it is to be understood that the invention needs not be limited to the disclosed embodiment. On the contrary, it is intended to cover various modifications and similar arrangements included within the spirit and scope of the appended claims which are to be accorded with the broadest interpretation so as to encompass all such modifications and similar structures.

What is claimed is:

1. A power converter, comprising:

a power module for converting an input voltage into an output voltage;

a feedback module electrically connected with said power module for generating a feedback voltage according to said output voltage; and

a control module electrically connected with said feedback module and said power module for comparing a reference duty cycle value with a duty cycle, generating a variable reference voltage according to the comparison between said reference duty cycle value and said duty cycle, comparing said variable reference voltage with said feedback voltage, and adjusting said duty cycle according to the comparison between said variable reference voltage and said feedback voltage, wherein said control module comprises:

a first comparing circuit for comparing said reference duty cycle value with said duty cycle, thereby generating an error duty cycle;

a first computing circuit electrically connected with said first comparing circuit for computing said error duty cycle, thereby generating and adjusting said variable reference voltage;

a second comparing circuit electrically connected with said first computing circuit and said feedback module for comparing said variable reference voltage with said feedback voltage, thereby generating an error voltage;

a second computing circuit electrically connected with said second comparing circuit for computing said error voltage, thereby generating and adjusting said duty cycle; and

a driving signal generator electrically connected with said second computing circuit and said power module for receiving said adjusted duty cycle from said second computing circuit and generating a driving control signal corresponding to said adjusted duty cycle.

2. The power converter according to claim **1**, wherein as said input voltage is changed, said variable reference voltage is adjusted by said control module, said duty cycle is correspondingly adjusted by said control module, and a driving control signal corresponding to said adjusted duty cycle is generated by said control module so as to control said power module.

3. The power converter according to claim **1**, wherein said first comparing circuit is electrically connected with said second computing circuit for receiving said duty cycle from said second computing circuit.

4. The power converter according to claim **1**, wherein said first comparing circuit is electrically connected with said driving signal generator for retrieving said duty cycle from said driving signal generator.

5. The power converter according to claim **1**, wherein after said driving control signal for controlling said power module is outputted from said control module, said driving control signal is fed back to said control module, wherein said fed-back driving control signal is received by said first comparing circuit, so that said corresponding duty cycle is retrieved from said driving control signal.

6. The power converter according to claim **1**, wherein as said input voltage is increased, said variable reference voltage is gradually increased, and said duty cycle is gradually increased by said control module.

7. A power supply system, comprising:

a high voltage bus;

a low voltage bus;

a power converter electrically connected between said high voltage bus and said low voltage bus, and comprising a control module for comparing a reference duty cycle value with a duty cycle, generating a variable reference voltage according to the comparison between said reference duty cycle value and said duty cycle, adjusting said duty cycle according to the comparison between said variable reference voltage and a feedback voltage, and generating a driving control signal corresponding to said adjusted duty cycle, thereby adjusting an output voltage from said power converter, wherein said control module comprises:

a first comparing circuit for comparing said reference duty cycle value with said duty cycle, thereby generating an error duty cycle;

a first computing circuit electrically connected with said first comparing circuit for computing said error duty cycle, thereby generating and adjusting said variable reference voltage;

a second comparing circuit electrically connected with said first computing circuit and said feedback module for comparing said variable reference voltage with said feedback voltage, thereby generating an error voltage;

a second computing circuit electrically connected with said second comparing circuit for computing said error voltage, thereby generating and adjusting said duty cycle; and

a driving signal generator electrically connected with said second computing circuit for receiving said adjusted duty cycle from said second computing circuit and generating said driving control signal corresponding to said adjusted duty cycle; and

a plurality of supply voltage generation circuits electrically connected with each other in parallel and electrically connected to said low voltage bus for converting said output voltage into respective supply voltages, thereby providing to corresponding loads.

8. The power supply system according to claim **7**, wherein said first comparing circuit is electrically connected with said second computing circuit for receiving said duty cycle from said second computing circuit.

9. The power supply system according to claim **7**, wherein said first comparing circuit is electrically connected with said driving signal generator for retrieving said duty cycle from said driving signal generator.

10. The power supply system according to claim **7**, wherein after said driving control signal is outputted from said control module, said driving control signal is fed back to said control module, wherein said fed-back driving control signal is received by said first comparing circuit, so that said corresponding duty cycle is retrieved from said driving control signal.

11. The power supply system according to claim **7**, wherein as an input voltage of said power converter is changed, said variable reference voltage is adjusted by said control module, wherein as said input voltage is increased, said variable reference voltage is increased, said duty cycle is gradually increased by said control module, and said output voltage is gradually increased according to said driving control signal.

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